AMBIENT POLLUTANT CONCENTRATIONS MEASURED BY A MOBILE LABORATORY IN SOUTH BRONX, NY

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Abstract

The objective this study is to characterize the ambient air quality the South Bronx, New York City (NYC) having high concentrations of diesel trucks and waste transfer facilities. We employed a mobile laboratory for continuous measurements of concentrations of fine particulate matter ($PM_{2.5}$), black carbon (BC), and gaseous pollutants at 6 locations for three to four weeks each during the period of April 2001 – February 2003. Integrated 24-hr $PM_{2.5}$ samples were also collected for elemental and PAHs analyses. South Bronx $PM_{2.5}$ and BC levels were compared to levels measured at Bronx PS 154 (NYSDEC site) and at Hunter College in the Lower Manhattan. Although the median daily $PM_{2.5}$ concentrations agreed within 20%, the median hourly BC concentrations were higher at all South Bronx sites ranging from 2.2 to 3.8 $\mu g\ m^{-3}$, compared to 1.0 to 2.6 $\mu g\ m^{-3}$ at Hunter College. Continuous Aethelometer measurements at additional 27 sampling sites in the South Bronx were conducted along major highways. BC concentrations varied within each site, depending on time-of-day, with a large spatial variability from site-to-site. Daily median BC concentrations varied from 1.7 to 12 $\mu g\ m^{-3}$ on the weekdays, and were lower (0.50 to 2.9 $\mu g\ m^{-3}$) on the weekends. Elemental concentrations were higher at all South Bronx sites than those at Hunter College for all measured elements but Ni and V, and at the Hunts Point, an industrial location, were approximately 2.5-fold higher. The average sum of 35 PAHs was 225 $ng\ m^{-3}$, which is 4.5 times larger than representative urban concentrations in Jersey City, NJ. Among the individual PAHs, 3,6-dimethylphenanthrene had the highest concentrations, and the overall PAH fingerprint differed from urban signal for Jersey City. Our data indicates that highways encircling the South Bronx are having a measurable adverse influence on residents' exposure to pollutants compared to other NYC areas.

Key words: urban air pollution, particulate matter, organic compounds, diesel traffic, black carbon

1. Introduction

In the Bronx, the most northern of the five boroughs of NYC, the rate of asthma hospitalizations increased 110 to 120 percent between 1987 and 1996, as compared to 35 to 50 percent increases in most other neighborhoods in NYC (Leighton et al., 1999). Additionally, these rates between 1991 and 1996 were higher for all ages of the Latino residents of the South Bronx than those of Manhattan and Brooklyn (Ray et al., 1998; Claudio et al., 1999). Although the origin of asthma is unquestionably multi-factorial, with important genetic, immunologic, and environmental components, the marked geographic and temporal variations strongly suggest that local environmental factors make a significant contribution to the pathogenesis and exacerbation of asthma, underscoring the need for an evaluation of this factor in urban neighborhoods within the South Bronx.

The South Bronx has large volumes of heavy vehicle traffic passing through it along several major highways (i.e., Interstates 87, 95, 278, and 895) that encircle the South Bronx, creating pollution that can affect local residents under any wind direction. In addition, there are multiple local industries and facilities that generate truck traffic, including Hunts Point Wholesale Markets (world's largest wholesale market), a municipal sewage sludge processing plant, a privately owned sludge drying plant, and 19 public and private waste transfer stations. The area also hosts a municipal waste water treatment plant and a large number of manufacturing facilities. All of this traffic results in high concentrations of truck activity and diesel emissions in the proximity of schools and residences in the South Bronx. At Hunts Point Market alone, some 12,000 trucks move in and out daily (NYS DOT, 2001). Indeed, it is very common to see schools, playgrounds, single family housing, waste transfer stations, and large apartment buildings, all within a few city blocks of each other. This type of zoning is generally less common in other parts of NYC, and the South Bronx represents one of the city's few remaining mixed-use zones where residential neighborhoods come into such close contact with heavy truck traffic (Claudio et al., 1998). Local community groups have raised the question whether this high concentration of truck activity and diesel emissions in the proximity of schools and residences are contributing to their very high prevalence of asthma. The New York State Department of Environmental Conservation (NYS DEC) measures neighborhood air pollution in the South Bronx at three centralized monitoring sites, currently located at public elementary and intermediate grade schools PS 154, IS 52, and IS 74 (sites U, S, and N on Figure 1, respectively). Currently, these sites report the following air pollution hourly parameters: PS 154 – $PM_{2.5}$, IS 52 – $PM_{2.5}$, PM_{10}, SO_2, O_3, and NO_x, IS 74 – $PM_{2.5}$. Given the elevation of these sites tens of feet above the street level, questions have arisen on whether these measurements represent the pollution at the ground level of the residents. Additionally, no speciation data is provided by NYS DEC sites.

To learn more about local South Bronx conditions, New York University (NYU) initiated a community-based South Bronx Air Pollution Study to examine the current environmental conditions, specifically as they relate to the siting of waste management facilities and traffic, and the regulatory and public policy issues that affect environmental decision-making. This study is carried out by the Nelson Institute of Environmental Medicine (NIEM) at NYU School of Medicine in collaboration with NYU's Robert F. Wagner Graduate School of Public Service and four community groups in the South Bronx (The Point, Youth Ministries, Nos Quedamos, Inc., and the Sports Foundation). In this paper, we report the elemental and organic composition of ambient $PM_{2.5}$ samples collected during this study.

2. Experimental Methods

The van for NYU's Mobile Laboratory was provided by the U.S. EPA for use in an EPA Cooperative Agreement, and remains on permanent loan, with support provided by the NYU Particulate Matter Health Effects Research Center. It is equipped with new environmental monitoring equipment, and heavy duty electrical wiring, which powers the air and meteorological monitoring equipment. It also houses on-board computers to store and process the exposure measurement data collected in the field. This mobile unit is a well-established facility that has maintained a good rapport with South Bronx residents, police and city government. The NYU Mobile Laboratory was employed periodically in 2000-2003 to collect the real-time measurement of pollutant levels needed for this research. Measurements included continuous PM_{10} mass (sequential sampler, NYU), $PM_{2.5}$ mass (TEOM with ACCU Sampler, R&P, inlet temperature XX°C, inlet design SPECIFICATIONS FROM MARTIN), BC (Aethelometer, Andersen Instruments, Magee Scientific, AE-14 dual channel, wavelength for the BC channel 880 nm, absorption cross-section SPECIFICATIONS FROM MARTIN), CO (Model 48C, Thermo Environmental Instrument Inc.), O_3 (Model 103-PC, Thermo Environmental Instrument Inc.), nitrogen oxides (Model 8840, Monitor Labs.), and SO_2 (Model 8850, Monitor Labs.). Additionally, $PM_{2.5}$ samples for gravimetric and elemental elements (via X-ray fluorescence (XRF)) analyses were collected daily at all sites for 24-hr on Teflon filters (Gelman "Teflo", 37 mm, 0.2 μm pore). In this paper, we discuss only the measurements of BC, $PM_{2.5}$ mass by TEOM, and $PM_{2.5}$ filter composition via XRF. Filter samples were stored at constant temperature and humidity (21±0.5°C, 40±5 %RH) until analyzed.

The integrated PAH samples were obtained only at the Crotona site during the period August,14 – September, 25 2002, using the method of Naumova et al. (2002). Sampled air was first passed through a $PM_{2.5}$ cyclone and then through two 47 mm quartz fiber filters (QFFs) to collect particulate-phase PAHs, then into a

stainless steel cylinder containing two polyurethane foam plugs (PUF) (diameter 25 mm, height 100 mm) to retain the gas-phase PAHs. The sampler was operated at a flow rate of 16.5 L min^{-1}; leading to sample volumes ranging from 73 to 188 m^3 depending upon the number of days over which the integrated sample was collected. After sampling, PUF plugs were placed in a pre-baked glass jar with aluminum foil-lined lids, while QFFs were placed in aluminum foil pouches. All samples were transported in a cooler and stored at 4°C until analyzed.

Filters collected for gravimetric and elemental analysis were equilibrated at NYU's weigh laboratory at constant temperature and humidity (21±0.5°C, 40±5 %RH) for 24 hours. Filter mass was measured on a microbalance (Model MT5, Mettler-Toledo). Analysis for 34 elements followed by non-destructive ED-XRF (Model EX-6600 –AF, Jordan Valley), and spectral software XRF2000v3.1 (US EPA and ManTech Environmental Technology, Inc.).

Analysis of QFFs and PUFs was performed under clean trace organic sample handling and techniques developed previously (Offenberg and Baker, 1997, 1999a, 1999b). Briefly, the PUF and QFF samples were spiked with a surrogate standard consisting of *d*10-acenaphthene, *d*10-anthracene, *d*10-fluoranthene, and *d*12-benzo[*e*]pyrene to determine the analytical recoveries of the PAHs. The QFFs and PUFs were then extracted for 24 hours in Soxhlet extractors with a mixture of petroleum ether:dichloromethane or acetone:hexane. The filter samples were solvent exchanged to hexane during the rotary evaporation step. An internal standard solution consisting of deuterated *d*8-naphthalene, *d*10-phenanthrene, *d*10-pyrene, and *d*12-benzo[*a*]pyrene was added to concentrated samples after the final nitrogen blow-down step. The final extracts were concentrated and analyzed on a high resolution GC/MS capillary detector (Hewlett-Packard 6890/5973) equipped with a 0.25 mm x 30 m DB-5 capillary column (0.25 mm film thickness; J&W Scientific). The MS was operating in Electron Impact ionization mode (70 eV), with data collected for target ions only (selected ion monitoring).

No significant breakthrough (i.e. < 5% on the back-up PUF) was observed for the PAH species reported here, with the exception of naphthalene, which is not included in the following results. Nearly 30% of the 3,6-dimethylphenanthrene was found on the second QFF, indicating that there may have been some adsorption to the filter surface or volatilization losses from the particles loaded onto the front filter during the multi-day sampling times, and resulting in less than quantitative collection. All other analytes exhibited no significant mass on the backup filter. 3,6-dimethylphenanthrene was kept for the results presented here, however the relatively high fraction on the backup filter must be noted.

Site selection for comprehensive sampling was based on preliminary sampling for BC (Aethelometer) at 27 locations (as shown in Figure 1) chosen according to the traffic density as well as local knowledge

regarding the nearby affected population (e.g., elementary school). This preliminary sampling was conducted during April and May, 2001. The BC concentrations were measured at each location (but not concurrently) for approximately 5 minutes during the morning (6 am to 9 am local time) and evening (4 pm to 7 pm local time) traffic rush hours. Each site was sampled at least four different weekdays and four different weekend days to get a representative mean concentration (Table 1). Based on the results, we selected six intensive sampling sites (shown in Figure 1) that represent both high and low concentrations of BC, and were they widely distributed within the South Bronx. Each site characteristics are listed in Table 2 along with Annual Average Daily Traffic (AADT) as reported by NYS DOT for 2001. Additional sampling site was located at lower Manhattan (on the roof of a two-storied building of Hunter College School of Health Science, 25th St. and 1st Ave.) and operated by another NYU research project. While the South Bronx is surrounded by three major interstates laden with semi-tractor trailers, Hunter College diesel traffic emissions are limited to delivery trucks on First and Second Avenues and local cross streets only, since no trucks are allowed on the nearby FDR Drive (reported AADT for FDR Drive between 23rd and 34th St. 125,637). The Hunter College site was used in this work for comparison of ambient pollutant levels.

3. Ambient Results and Discussion

The BC concentrations measured at 27 different sites (shown in Table 1) indicate variability within each site depending on day of the week, with weekdays being highest, as well as a large spatial variability from site-to-site. Mean BC concentration varied from 1.7 to almost 12 μg m^{-3} on the weekdays, and was significantly less (0.5 to 2.9 μg m^{-3}) on the weekends (both a.m. and p.m. rush hours were averaged in weekday and weekend values). The BC levels in the morning were higher that those in the evening at all sites, likely due to the poorer mixing of the atmosphere in the morning hours. A separate investigation of the relationship between traffic counts and air pollutants conducted at PS 154 revealed that both peak BC and oxides of nitrogen were related to hourly variations in nearby I-87 truck traffic (Thurston et al., 2003). We did not have the traffic count data for each individual site, and use of NYS DOT annual average daily traffic densities sited in the Methods section did not provide a good correlation, most likely due to our limited dataset. Additionally, the true daily volumes on highways may vary widely from the AADT. Considerably higher or lower values often result in areas of seasonal activities (e.g., holidays, weather, pollution episodes) when counting weekend versus weekday traffic.

We compared ambient TEOM $PM_{2.5}$ and BC concentrations measured by the Mobile Laboratory at various parts of the South Bronx to the ones simultaneously measured at Hunter College and by NYS DEC at

PS 154. The comparison of these three sites indicated that although the median daily TEOM $PM_{2.5}$ concentrations (shown in Figure 2) at all three concurrent sites agreed within 20%, the median hourly BC concentrations (shown in Figure 3) were higher at all south Bronx sites. Notably, the intervals within which lies 50% of the data (each box in Figure 2 and 3) were wider for the samples collected at the South Bronx intensive sampling sites.

The average daily $PM_{2.5}$ mass concentration for all six intensive sampling sites was 16.2±5.1 μg m^{-3}. However, as shown in Figure 4, these concentrations were on average 35% lower on weekend than those on weekdays except for Crotona, where weekend $PM_{2.5}$ levels were slightly higher, likely due to the active use of the park by the local residents. The reason why a weekend decrease in $PM_{2.5}$ was not observed at 138th St is not clear. Average daily BC concentrations for all six sites was 2.7±1.1 μg m^{-3}. Again, the averages were about 40% lower on weekends vs. the weekdays which can be explained by reduced diesel truck traffic on the surrounding highways.

Table 3 presents average concentrations of elements observed in the $PM_{2.5}$ samples at the six sites. Although the XRF analysis was done for 34 elements, here we report only elements detected in more than 25% samples per site. In our treatment of XRF data, the element was considered to be detected if the value was larger than three times the uncertainty of the measurement. In calculating the arithmetic averages, the values of the non-detected elements were replaced with the three times uncertainty of the measurement. S, K, Ca, Fe, Ni, and Zn were detected in >75% of samples at all sites. Elements that were detected in less than 50% of samples include Cr, Sb, and As. The sum of all analyzed elements contributed 10.5 to 17.3% of the $PM_{2.5}$ mass. As shown in Figure 5, elemental concentrations measured in this work agree well with previously reported data for samples collected in 3 NYC neighborhoods of Harlem, Bronx, and Queens (Kinney et al., 2002). On average, S was higher in samples collected during summer months due to increased photochemical gas-to-particle conversion processes. In winter, we observed higher concentrations of Ni and V, two elements known to be enriched in residual fuels and their combustion products (Cooper and Watson, 1980). Notably, these elements were higher at the Hunter College site than at the concurrent Bronx site, presumably due to the influences of local power plants located in Manhattan and across the East River in Queens.

An inter-comparison within all sites (Table 3) showed that mean fraction concentrations of all elements but Cl, Ni, and V were somewhat higher at the South Bronx than those at concurrently collected at Hunter College. Comparison of concurrent South Bronx and Hunter College samples showed consistently higher Fe, Cu, Zn, and Ba at the former, but little spatial variation of elements of crustal origin such as Al and Si. Average

Cr, Mn, Fe, Co, Cu, Zn, Ba, and Pb in Hunts Point site samples were up to 2.5-fold higher for these elements at the other sites. We suspect that this location was affected by the emissions from the nearby subway entrances, since high concentrations of Fe, Ba, and Cu were similarly observed in a subway study by Furuya et al. (2001). At other Bronx locations, high Ba levels are attributed to the wear of automobile break pads, and, thus, are expected to be elevated in higher traffic density area. The subway could also be the source of elevated Na and highest median Cl concentration (median data not shown) observed in Hunts Point samples as was reported for the Washington, DC, subway (Birenzvige et al., 2003). Concentrations of most elements at PS 154 were almost twice as large in 2002 than in 2001. Since the prevalent wind directions for both sampling periods were comparable, i.e., the frequency of southerly winds were 50.1% in 2001 and 58.1% in 2002, and northerly winds 35.9% and 23.3%, respectively, we speculate that the observed concentrations could partially be attributed to local activities: during 2001 sampling period the school was not in session.

Total (gas phase + particle-bound) Σ_{35}-PAH concentrations (the sum of 35 individual PAHs listed below) collected at the Crotona site ranged from 106 ng m^{-3} to 374 ng m^{-3} (geometric mean of all Σ_{35}-PAH of 225 ng m^{-3}). These observed concentrations approach the highest ever reported in the US. For comparison, Σ-PAH concentrations ranged 27 – 430 ng m^{-3} in Chicago (Simcik et al., 1997), 92 ng m^{-3} in Denver, CO (Foreman and Bidleman, 1992), and 19.5 – 114 ng m^{-3} in urban Baltimore, MD (Offenberg and Baker, 1999).

Figure 6 shows the comparison of Crotona Σ-PAHs to the closest representative urban site at Jersey City, NJ, where total Σ-PAHs measured once every twelve days over the period July 5, 1998 – October 3, 2000, and averaged 52.8 ng m^{-3} (Gigliotti et al., 2000). This translates into the total Σ-PAH concentrations at Crotona being 4.5-fold higher than those measured in Jersey City. More than 97.5% of the total Σ-PAH measured at Crotona was found to be in the gas phase. For comparison, concentrations of PAHs in during summer 1996 in urban Baltimore averaged 43.7 ± 32.5 ng m^{-3}, with 92% found in the gas phase (Offenberg and Baker, 1999). While the gas phase concentrations reported here were higher than those measured in Jersey City by a factor of 4.9, the particle bound concentrations were only higher by a factor of 1.3. Additionally, the Crotona concentrations shown in Figure 6 were measured as integrated samples over periods of three to eight days and as such represent time weighted average concentrations over several day periods. This several day integration dampens extremes that otherwise would have been seen in shorter integrated samples, such as the 24 hour sampling strategy utilized by Gigliotti et al., (2000).

Average concentrations of individual gas phase and particle-bound PAHs are shown in Figure 7. Gas phase concentrations were dominated by phenanthrene, 3,6-dimethylphenanthrene, and mono-

methylphenanthrenes + mono-methylanthracenes. Particle phase concentrations were dominated by 3,6-dimethylphenanthrene, with significant contributions of benzo[g,h,I]perylene, indeno[1,2,3-c,d]pyrene and coronene. For all samples, 3,6 dimethylphenanthrene was greatly enhanced, representing approximately 35% of the total Σ-PAH, and suggesting a strong local source of this PAH. Overall, the relative contributions to total PAHs (the PAH "fingerprint") differed from that in Jersey City, as shown in Figure 7. A majority of the difference in total PAH concentrations relate to large enrichment in 3,6-dimethlyphenanthrene, phenanthrene, mono-methylphenanthrenes + mono-methylanthracenes at the Crotona location.

Jersey City is a highly urbanized location on the west bank of Hudson River across the Lower Manhattan. It is just east of I-95 (NJ Turnpike), and is a major commute route to Holland Tunnel via I-78. This area experiences daily rush hour traffic and slow downs for toll booths similar to the South Bronx. While Jersey City is located upwind of Manhattan, South Bronx is downwind of Manhattan and New Jersey, possibly experiencing the cumulative effect of pollution sources as well as local. Lee et al., (2004) describe the apportionment of ambient concentrations to sources of PAHs in the airshed over the lower Hudson River Estuary. The large differences in total PAH concentration and relative contributions may be suggestive of completely different sources rather then just traffic contributes to the level of organic pollutants in the South Bronx.

4. Summary

An intensive $PM_{2.5}$ speciation sampling study was carried out at six sites in South Bronx, NY during the period of April 2001 – February 2003. The results for BC and elemental composition were compared to those at Lower Manhattan (Hunter College). The BC concentrations varied within each site depending on time of day, with a large spatial variability from site-to-site. The average daily $PM_{2.5}$ mass concentration for all six sites was 16.2±5.1 μg m^{-3}. The sum of 34 elements analyzed by XRF contributed 10.5 to 17.3% of the $PM_{2.5}$ mass. Elemental concentrations were higher at all South Bronx sites than those at Hunter College for all measured elements but Ni and V, with highest concentrations for most transition group elements reported at Hunts Point site.

Low volume integrated sampling for gas and particle phase PAHs exhibited high concentrations in the Bronx. While the sum concentrations were similar to those observed in other heavily populated urban centers, such as Chicago, Baltimore and Denver, the relative composition was distinctive. The relative contribution of

3,6-dimethylphenanthrene was high, and suggests a strong source of this compound, and possibly other PAHs proximate to the sampling location.

Overall, our sampling data indicate that the major highways encircling the South Bronx, as well as other local sources, are having a measurable adverse impact on residents' exposures to air pollution, even relative to other NYC area locales.

Acknowledgement

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References

Birenzvige, A., Eversole, J., Seaver, M., Francesconi, S., Valdes, E., Kulaga, H. 2003. Aerosol characteristics in a subway environment. Aerosol Science and Technology 37, 210-220.

Claudio, L., Torres T., Sanjurjo, E., Sherman, L.R., Landrigan, P.J. 1998. Environmental health sciences education – a tool for achieving environmental equity and protecting children. Environmental Health Perspectives 106, Supplement 3, 849-855.

Claudio, L., Tulton, L., Doucette, J., Landrigan, P.J. 1999. Socioeconomic factors and asthma hospitalization rates in New York City. Journal of Asthma 36(4), 343-50.

Cooper, J.A., and Watson, J.G. 1980. Receptor oriented methods of air particulate source apportionment. J. Air Pollut. Control Ass. 30,1116-1125.

Foreman and Bidleman, 1990. "Semi-volatile organic compounds in the ambient air of Denver, Colorado." Atmospheric Environment 24A, 2405-2416.

Furuya, K., Kudo, Y., Okinaga, K., Yamuki, M., Takahashi, S., Araki, Y., Hisamatsu, Y. 2001. Seasonal variation and their characterization of suspended particulate matter in the air of subway stations. Journal of Trace and Microprobe Techniques 19(4), 469-485.

Gigliotti, C.L., Dachs, J. Nelson, E.D., Brunciak, P.A., Eisenreich, S.J. 2000. "Polycyclic aromatic hydrocarbons in the New Jersey coastal atmosphere." Environmental Science and Technology 34, 3547-3554.

Lee, J.H., Gigliotti, C.L., Offenberg, J.H., Eisenreich, S.J., and Turpin, B.J. 2004. Sources of Polycyclic Aromatic Hydrocarbons to the Hudson River Airshed. Atmospheric Environment, in review.

Leighton, J., Matte, T., Findley, S. 1999. Asthma prevalence among school children in a Bronx community. Asthma Conference, February 9, 1999. Atlanta, GA: Centers for Disease Control and Prevention. pp. 26.

Naumova, Y.Y., Eisenreich, S.J., Turpin, B.J., Weisel, C.P., Morandi, M.T., Colome, S.D., Totten, L.A., Stock, T.H., Winer, A.M., Alimokhtari, S., Kwon, J., Shendell, D., Jones, J., Maberti, S., Wall, S.J., 2002. Polycyclic aromatic hydrocarbons in the indoor and outdoor air of three cities in the US. Environmental Science and Technology 36 (12), 2552–2559.

New York State Department of Transportation 2001. Traffic volume report for Bronx County. www.dot.state.ny.us/tech_serv/high/countfiles/bronx.pdf.

Offenberg, J. H., Baker, J. E. 1997. Polychlorinated biphenyls in Chicago precipitation: enhanced wet deposition to near-shore Lake Michigan. Environmental Science and Technology 31, 1534-1538.

Offenberg, J. H., Baker, J. E. 1999a. Influence of Baltimore's urban atmosphere on organic contaminants over the Northern Chesapeake Bay. Journal of the Air and Waste Management Association 49, 959-965.

Offenberg, J. H., Baker, J. E. 1999b. Aerosol size distributions of polycyclic aromatic hydrocarbons in urban and over-water atmospheres. Environmental Science and Technology 33, 3324-3331.

Ray, N.F., Thamer, M., Fadillioglu, B., Gergen, P.J. 1998. Race, income, urbanicity, and asthma hospitalization in California - A small area analysis. Chest 113 (5), 1277-1284.

Simcik, M.F., Zhang, H.X., Eisenreich, S..J, Franz, T.P. 1997. Urban contamination of the Chicago/coastal Lake Michigan atmosphere by PCBs and PAHs during AEOLOS. Environmental Science and Technology 31, 2141-2147.

Thurston, G., Kendall, M., Maciejczyk, P., Lall, R., Gorczynski, J., Blaustein, M., Clemente, J. 2003. A pilot study of traffic exposures and their health effects among South Bronx children with asthma. Presented at 2003 American Association for Aerosol Research Particulate Matter Meeting. Particulate Matter: Atmospheric Sciences, Exposure and the Forth Colloquium on PM and Human Health, Pittsburgh, PA, March 31-April 4.

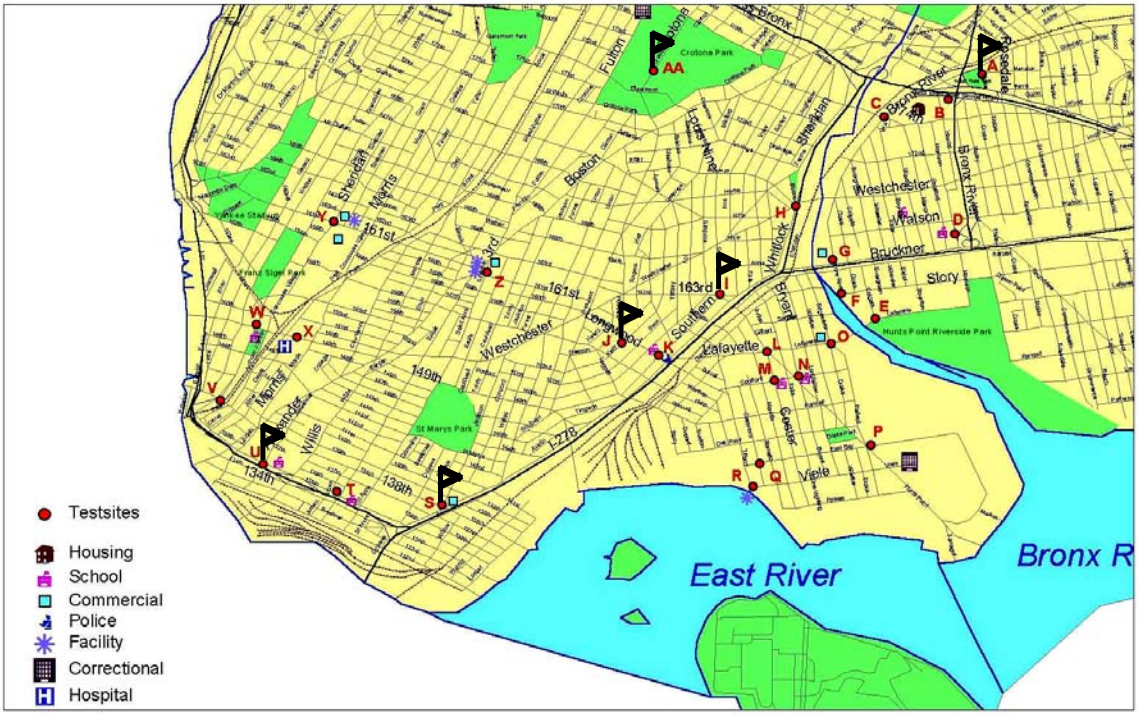

Figure 1. Location of sampling sites in South Bronx. Preliminary sites are marked by shaded circles and letters. Final comprehensive sites for mobile laboratory measurements are marked by flags.

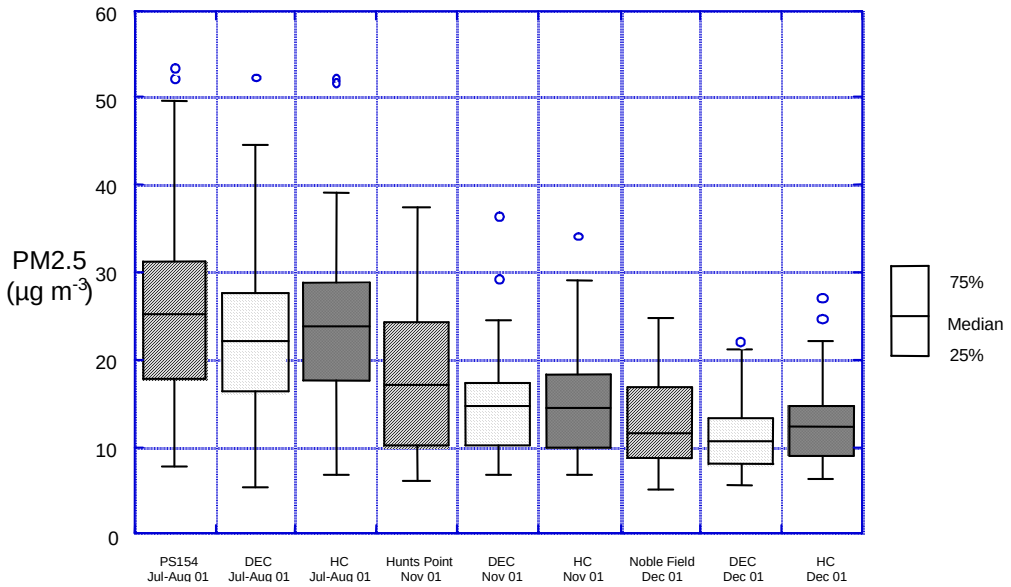

Figure 2. Daily $PM_{2.5}$ concentrations ($\mu g\ m^{-3}$) measured at the NYS DEC (DEC), Hunter College (HC), and at 3 sites in the South Bronx (PS 154, Hunts Point, and Noble Field). Circles are outliers (measurements outside the 10^{th} and 90^{th} percentile).

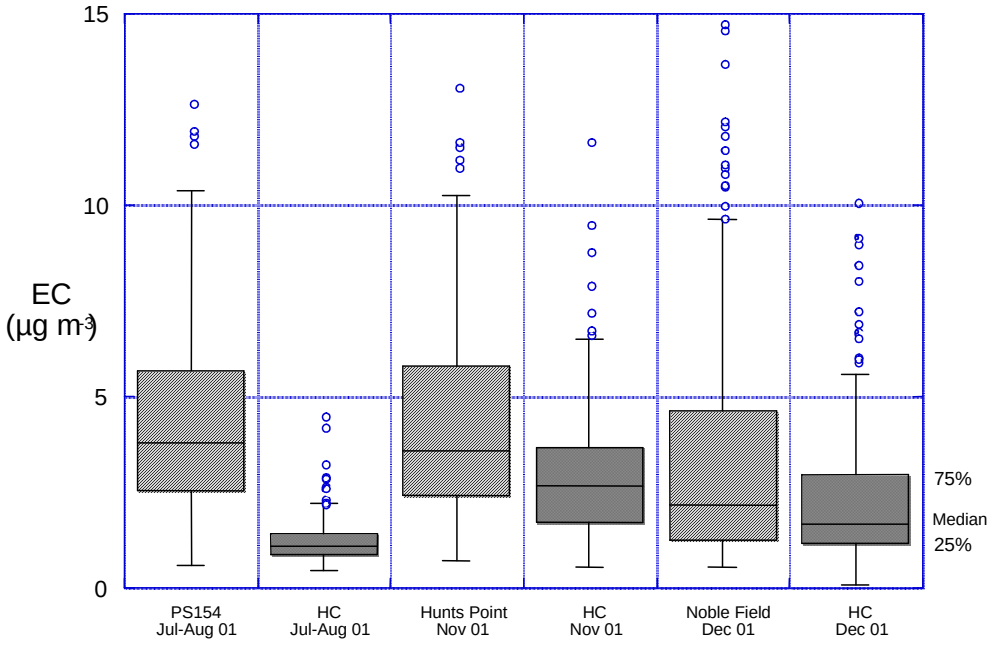

Figure 3. Concurrent hourly BC concentrations (µg m^{-3}) measured at three South Bronx sites and Hunter College (HC). Circles are outliers (measurements outside the 10^{th} and 90^{th} percentile).

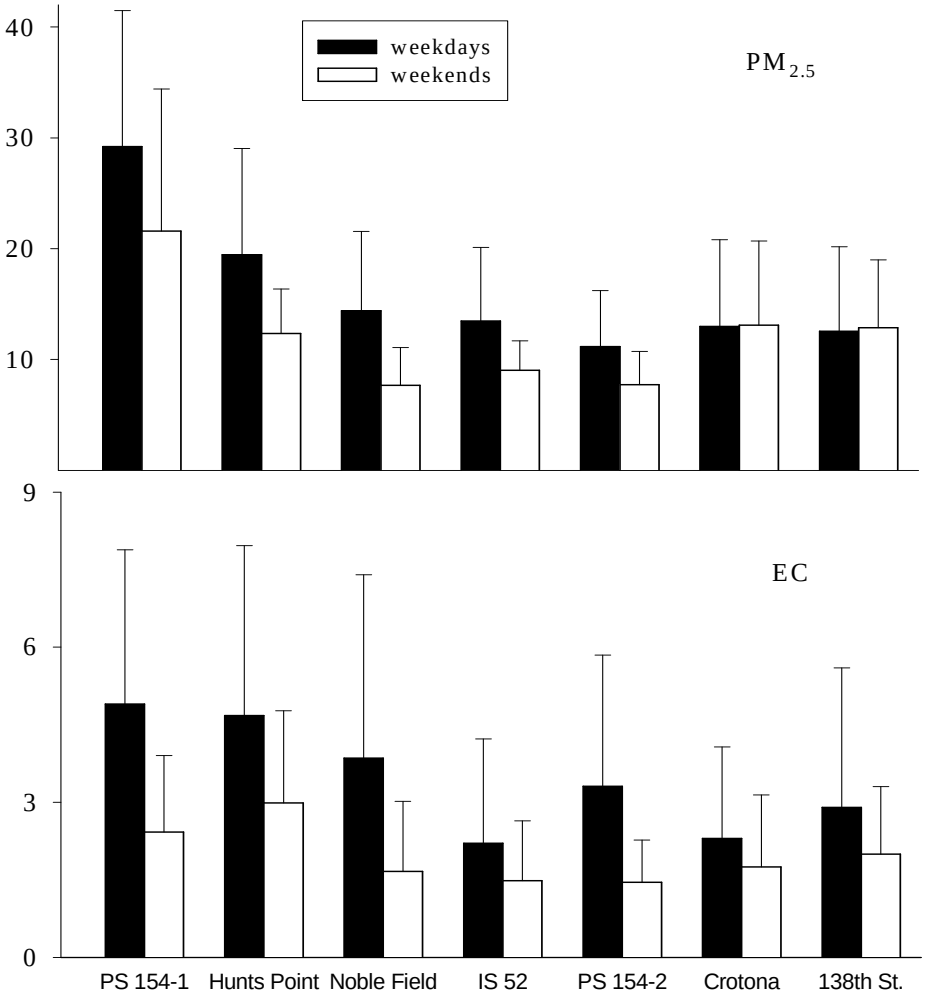

Figure 4. The arithmetic mean of daily mean concentrations of PM2.5 and BC ($\mu g\ m^{-3}$) measured at the South Bronx sites. Error bars are the standard deviation of the arithmetic mean.

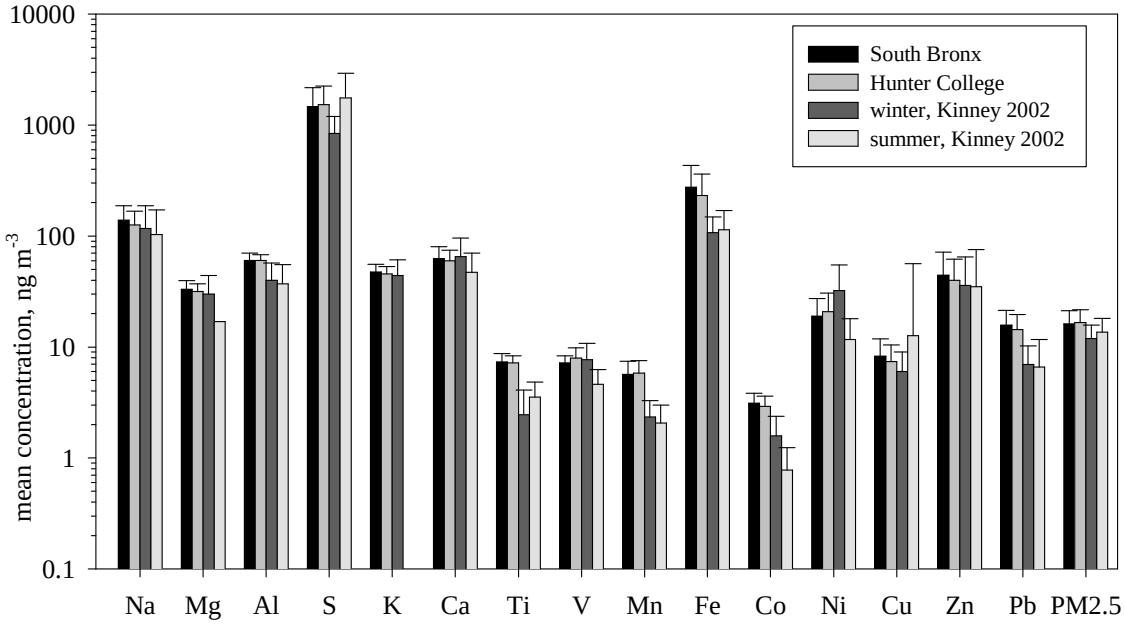

Figure 5. Mean daily elemental concentrations (ng m^{-3}) in samples measured concurrently at the South Bronx sites and Hunter College. Winter and summer means are adapted from Kinney et al., 2002. $PM_{2.5}$ concentrations are in $\mu g\ m^{-3}$.

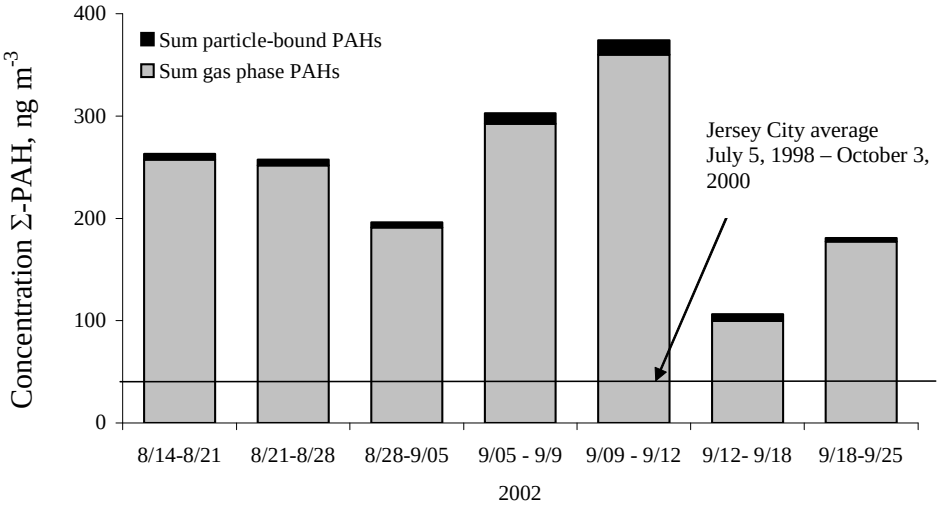

Figure 6. Total (gas phase + particle-bound) Σ-PAH concentrations (ng m^{-3}) measured at the Crotona site. Jersey City, NJ average from Gigliotti et al., 2000.

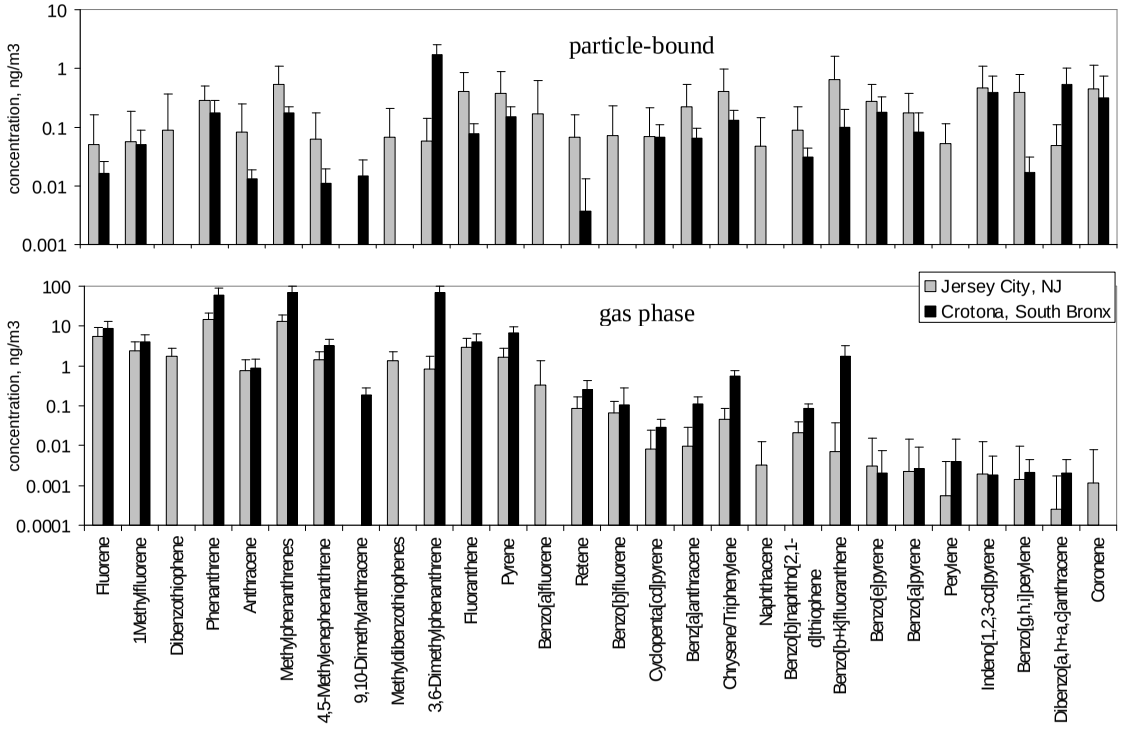

Figure 7. Comparison of mean concentrations (ng m^{-3}) of individual PAHs between the Crotona site and Jersey City, NJ (from Gigliotti et al., 2000).

Table 1. Mean BC concentration ($\mu g\ m^{-3}$) measured at 27 preliminary sites

site	all	day of the week		weekdays	
		weekday	weekend	AM	PM
A	5.2 ± 4.8	7.4 ± 5.2	2.6 ± 2.5	8.6 ± 6.3	6.1 ± 3.5
B	3.9 ± 3.3	5.4 ± 3.3	2.2 ± 2.3	8.2 ± 2.4	2.9 ± 1.5
C	5.4 ± 8.0	6.1 ± 4.9	4.6 ± 10.4	8.7 ± 5.1	3.0 ± 2.2
D	3.3 ± 3.1	4.9 ± 3.5	1.6 ± 0.9	6.3 ± 4.3	3.4 ± 1.4
E	3.8 ± 5.6	6.3 ± 6.4	1.2 ± 1.0	9.1 ± 7.5	3.3 ± 3.2
F	5.2 ± 5.0	7.7 ± 5.3	2.2 ± 2.3	10.5 ± 5.5	4.8 ± 3.2
G	5.8 ± 7.1	9.9 ± 8.2	1.7 ± 1.5	11.6 ± 9.1	8.0 ± 6.8
H	9.4 ± 12.4	15.1 ± 14.7	3.0 ± 2.7	23.3 ± 16.6	7.4 ± 6.5
I	5.4 ± 6.0	8.9 ± 6.7	1.8 ± 1.2	11.5 ± 8.5	6.2 ± 2.6
J	2.4 ± 2.0	3.5 ± 2.2	1.1 ± 0.5	4.4 ± 2.4	2.6 ± 1.5
K	3.0 ± 3.5	4.5 ± 4.2	1.3 ± 0.6	6.4 ± 5.2	2.6 ± 1.5
L	3.2 ± 3.4	4.8 ± 4.0	1.5 ± 1.5	6.4 ± 4.0	2.8 ± 3.0
M	2.6 ± 2.4	3.9 ± 2.7	1.2 ± 0.6	5.2 ± 3.0	2.6 ± 1.6
N	2.2 ± 2.0	3.2 ± 2.4	1.1 ± 0.6	3.7 ± 2.5	2.8 ± 2.2
O	4.5 ± 3.4	5.3 ± 3.1	3.7 ± 3.6	4.7 ± 2.4	5.9 ± 3.7
P	5.3 ± 6.2	6.7 ± 7.6	3.8 ± 3.9	10.0 ± 8.9	3.2 ± 3.3
Q	2.9 ± 3.0	4.3 ± 3.5	1.5 ± 1.0	4.8 ± 2.2	3.6 ± 4.6
R	3.1 ± 3.1	4.6 ± 3.5	1.4 ± 1.0	6.4 ± 3.6	2.5 ± 2.1
S	5.9 ± 6.3	8.6 ± 6.6	1.5 ± 1.1	10.1 ± 7.8	7.3 ± 5.3
T	6.8 ± 8.8	9.9 ± 10.1	1.9 ± 1.0	13.2 ± 12.2	6.1 ± 4.9
U	4.2 ± 4.0	5.8 ± 3.6	1.7 ± 3.3	6.5 ± 3.9	5.1 ± 3.1
V	3.6 ± 2.8	5.0 ± 2.7	1.5 ± 0.8	6.2 ± 2.9	3.9 ± 2.0
W	6.2 ± 9.2	9.4 ± 11.0	1.9 ± 2.0	10.8 ± 10.4	8.2 ± 11.6
X	3.6 ± 2.9	5.0 ± 2.8	1.7 ± 1.3	6.0 ± 2.8	4.0 ± 2.4
Y	4.3 ± 3.2	4.6 ± 2.7	3.9 ± 3.7	6.6 ± 2.3	2.7 ± 1.3
Z	3.2 ± 3.3	4.5 ± 3.7	1.5 ± 1.5	6.3 ± 3.9	2.2 ± 1.7
AA	3.6 ± 3.3	4.9 ± 3.6	1.6 ± 1.3	6.8 ± 3.9	2.9 ± 1.9

Table 2. Site information for the intensive measurements with the mobile laboratory

site ID on Figure 1	site name	sampling dates	site characteristics
U	PS 154	July 27 – August 29, 2001, and April 23 – May 20, 2002	On a corner of 135th St. and Alexander Ave. next to Bronx public school 154. PS 154 is also a location of NYS DEC monitoring station. This site was in immediate proximity of I-97 (Major Deegan Expressway) that had 110, 000 AADT for 2001.
I	Hunts Point	November 8 – 29, 2001	Above the underground Hunts Point Station of the NYC subway system, in immediate proximity to an elevated section of I-278 (Bruckner Expressway) and the exit ramp to Hunts Point Avenue that leads to the Hunts Point Wholesale Market district. The AADT count for 2001 was over 117, 000.
A	Noble Field	December 4, 2001 – January 2, 2002	In residential area, on the grounds of the Noble Field Park, a small recreational park that borders I-95 (Cross Bronx Expressway) and the Bronx River Parkway, a 6-lane limited access road that excludes the truck traffic. For this location the 2001 AADT was over 124, 000.
J	IS 52	March 27 – April 21, 2002	4 blocks northwest of I-278. This area is more residential, and also has an established NYS DEC monitoring station.
AA	Crotona	August 13 – October 11, 2002	On the grounds of Crotona Park, a large public recreational park located 2 blocks south of I-95. Despite the park-like setting, this site is influenced by traffic on the Crotona Avenue that runs through the park, in addition to some 148, 200 AADT from I-95 under northerly winds.
S	138th Street	January 6 – February 11, 2003	On a corner of 138th street and Bruckner Boulevard, in immediate proximity of I-278. This site was on the same section of route for AADT as the Hunts Point.

Table 3. Summary of elemental composition of PM2.5 samples, mean (standard deviation), ppm. Values in bold – elements detected >76% of samples, in underlined – 51-75%, regular font – 26-50%, not reported - <25%.

	July 27 - August 29, 2001		November 8 - 29, 2001		December 4, 2001-January 2, 2002		March 27 - April 21, 2002	April 23 - May 20, 2002	August 13 - October 11, 2002	January 6 - February 11, 2003
	PS154	Hunter College	Hunts Point	Hunter College	Noble Field	Hunter College	IS52	PS154	Crotona	138th St.
	n=34	n=34	n=21	n=21	n=29	n=23	n=22	n=37	n=59	n=35
Na	3,919 (5779)	5,482 (6775)	6,924 (6698)	6,990 (9754)	6,320 (4634)	4,092 (2190)	**15,927** (13180)	10,161 (8283)	**9,877** (11338)	**11,325** (9231)
Mg	1,221 (714)	1,374 (1009)	1,940 (923)	1,673 (1296)	2,294 (908)	1,733 (603)	3,210 (1615)	5,145 (5240)	2,419 (1659)	2,287 (1724)
Al	2,457 (1253)	2,790 (1280)	3,733 (1508)	3,602 (1516)	4,299 (2103)	3,700 (1477)	5,226 (2714)		3,620 (1914)	3,193 (1382)
Si	4,530 (1790)	5,526 (2775)	**7,693** (2039)	6,197 (2916)	**6,995** (2311)	**7,097** (2684)	**12,081** (8044)	13,011 (6833)	**5,596** (2716)	**5,383** (1907)
S	**91,663** (38084)	**110,319** (29025)	**74,688** (18052)	**63,284** (15832)	**84,271** (17445)	**68,657** (13005)	**114,496** (17424)	**95,674** (23064)	**102,872** (33796)	**106,061** (19238)
Cl			2,510 (2128)	3,640 (7734)	1,271 (690)	1,670 (1280)	1,565 (1661)		1,354 (2135)	**4,272** (4725)
K	**1,563** (670)	**1,890** (646)	**3,513** (818)	**3,094** (886)	**3,742** (1132)	**3,013** (715)	**4,112** (1703)	**4,394** (2366)	**3,441** (1885)	**4,101** (944)
Ca	**2,285** (1121)	**2,756** (1111)	**5,741** (1936)	**3,762** (1555)	**5,770** (1586)	**4,165** (1661)	**5,049** (1452)	**5,549** (1880)	**3,903** (2187)	**3,727** (1159)
Ti	288 (223)			333 (156)			497 (274)		419 (175)	213 (112)
V	**303** (147)	**466** (239)	**496** (240)	**711** (306)	**533** (258)	**666** (281)	**488** (181)	704 (607)	375 (198)	**441** (179)
Cr			227 (128)	177 (95)						
Mn	184 (87)	361 (652)	**468** (223)	334 (179)	340 (139)	337 (158)	319 (131)	713 (729)	225 (102)	**197** (108)
Fe	**9,654** (4549)	**9,771** (7511)	**34,359** (24368)	**10,940** (4009)	**18,305** (5595)	**11,104** (3978)	**11,384** (3366)	**20,388** (6575)	**11,642** (4818)	**397** (282)
Co	98		255 (100)	**189** (125)	275 (126)	**214** (119)	174 (72)	394 (384)	126 (55)	25,763 (13277)
Ni	**384** (155)	**755** (352)	**1,980** (1026)	**2,415** (1331)	**2,464** (1215)	**2,968** (1662)	**1,482** (810)	1,002 (692)	**804** (394)	**184** (76)
Cu	**299** (171)	**291** (189)	**748** (637)	**333** (184)	**530** (168)	366 (274)	396 (182)	808 (604)	**310** (134)	**1,637** (469)
Zn	**1,020** (429)	**1,233** (568)	**5,699** (2651)	**2,544** (1567)	**4,769** (1638)	**3,163** (1132)	**2,870** (1068)	**2,868** (2124)	**1,727** (826)	**344** (123)
As				355 (182)						
Se	154 (75)		262 (123)	193 (72)	340 (164)		298 (159)			315 (160)
Br	**238** (97)	**233** (105)	**472** (284)	**366** (146)	**529** (200)	**352** (92)	**603** (221)	914 (821)	234 (146)	**226** (83)
Sr	150 (102)		224 (126)	162 (80)	274 (141)		282 (138)	898 (1312)	232 (166)	**491** (171)
Sb	556 (332)				1,114 (478)					
Ba	**792** (417)	**539** (320)	**2,320** (1725)	615 (280)	**1,815** (667)	677 (272)	843 (355)	2,447 (2331)	1,161 (570)	**548** (278)
Pb			776 (559)	640 (387)					410 (230)	**1,936** (1124)
%mass	12.2 (4)	14.4 (2.9)	15.8 (2.6)	11.1 (3.5)	14.7 (3.2)	11.4 (2.6)	17.9 (3.8)	19.1 (5.7)	15.5 (2.6)	17.5 (3.8)